SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 153, NUMBER 5

(PUBLICATION 4753)

Roebling Fund

A LONG-RANGE FORECAST OF TEMPERATURE FOR 19 UNITED STATES CITIES

By

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AND

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CITY OF WASHINGTON
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INTRODUCTION

THE RESEARCH findings set forth in this study are the concluding part of an investigation outlined and ordered by Dr. Samuel Pierpont Langley in 1905. Its objects, and the successful progress made in the ensuing 63 years, are briefly but lucidly summarized in *Solar Variation, a Weather Element,* a paper prepared by C. G. Abbot at the invitation of President Seitz of the National Academy of Sciences, and published in its Proceedings for December 1966.[1] Besides filling volumes 2 to 7 of the *Annals of the Astrophysical Observatory of the Smithsonian Institution,* explanations and details are contained in the more than 150 papers published by members of the staff of the Astrophysical Observatory during the years 1900 to 1968 in the *Smithsonian Miscellaneous Collections.* A few are published in other scientific books and periodicals of the United States and foreign countries. A list of the most important of these 150 papers is appended.

It is now three generations since Dr. Langley gave his directive

[1] Reprints of this article are available from the Publications Distribution Section, Smithsonian Institution Press, Washington, D.C. 20560. See footnote 6 for complete citation.

of 1905. A summary of the most important results which flowed from it may be surprising to some of this generation.

1. Though Langley deprecated our seeking to determine the exact value of the solar constant of radiation, we had to have the apparatus necessary to obtain it in order to fulfill his other objects. Indeed, as early as 1930, we did obtain a very good value of the solar constant. By 1952, as the average of about 9000 daily values observed from several high mountains, we obtained, from results of the years 1923 to 1952, our published value: 1.946 calories per cm^2 per minute. During the past year (1967-1968) space observers, observing the sun from outside the atmosphere, have twice obtained 1.95 calories, as published by Dr. A. J. Drummond and associates.[2] So there is essentially perfect agreement.

2. From 1902 to 1914 the staff of the Astrophysical Observatory (then including Andrew Kramer, instrumentmaker, and Messrs. Fowle, Aldrich, and Abbot, observers) designed and constructed about ten instruments for observing solar radiation. These included: the absolute pyrheliometer, four kinds of secondary pyrheliometers, the pyranometer, the two-mirror coelostat, the perfected vacuum-bolometer, and several devices for the spectro-bolometer, and for reducing solar measurements.[3]

3. From 1905 to 1920 about six months each year were spent in solar radiation work on Mt. Wilson, measuring the atmospheric transmission, and computing the solar constant, by Langley's "long method." H. H. Clayton—making high, medium, and low groups of our results—proved by 1916 the sun's radiation to be a controlling world weather element.

4. In 1918 a new station was established at Calama, in the nitrate desert of Chile, to observe the sun's radiation *daily* throughout the year. Clayton found a close correlation between Mt. Wilson and Calama, though situated in opposite hemispheres. But we needed daily measures from a *pair* of *mountain* stations, and a *solar constant method* so quick as to avoid changes of atmospheric transparency. John A. Roebling's generosity enabled us to occupy Mt. Harqua Hala (5672 feet) in Arizona, and also Mt. Montezuma (9000 feet) near Calama throughout several years beginning in 1920.

5. A. F. Moore at Calama, making daily measures of radiation

[2] Eppley Laboratory, Reprint Series No. 33, 1967.

[3] See C. G. Abbot, *Solar Variation and Weather—A Summary of the Evidence, Completely Illustrated and Documented,* Smithsonian Miscellaneous Collections, volume 146, No. 3 (Publication 4545).

from a zone of sky near the sun with the pyranometer, laid the foundation for the "short method" of determining the atmospheric spectral transparency in 40 wavelengths. The "short method" for the solar constant was perfected in 1923, and applied to measure the solar constant daily for 9000 days at several high mountain stations over a period of 30 years, from 1923 until 1952.[4]

6. Meanwhile, Dr. George E. Hale, at Mt. Wilson, discovered the cycle of 22 years 9 months in the magnetic fields of sun spots. Our 30-year record of daily solar constant measures plainly revealed a corresponding master cycle of 273 months in solar variation. It has an amplitude of 3 percent and, like music, has many exact subordinate harmonics. We discovered 27 such harmonics in solar variation, all exact fractions of 273 months. We found also nonperiodic trends, up and down, for the sun's radiation. These opposing trends, occurring about twice a month, and with amplitudes of approximately 1 percent, were found to be an important cause of temperature changes.

7. Following Dr. Langley's prevision, we found all of the 27 regular solar harmonics, and also all of the nonperiodic trends, to be plainly effective in weather.

8. Finally, Langley's hope for long-range weather predictions also are confirmed. In five publications in the Smithsonian Miscellaneous Collections series [5] forecasts of precipitation at 55 cities on six continents were tabulated for as much as two generations in advance. In publication 4711, identified below in footnote 5, and in this publication, long-range forecasts are also tabulated for 30 cities in the United States. In *Solar Variation, a Weather Element,*[6] Figure

[4] See C. G. Abbot, *Forecasting from Harmonic Periods in Precepitation,* Smithsonian Miscellaneous Collections, volume 148, No. 8, 1966 (Publication 4659).

[5] See C. G. Abbot, *Sixty-Year Weather Forecast,* Smithsonian Miscellaneous Collections, volume 128, No. 3, 1955 (publication 4211).

C. G. Abbot, *A Long-Range Forecast of United States Precipitation,* Smithsonian Miscellaneous Collections, volume 139, No. 9, 1960 (Publication 4390).

C. G. Abbot, *Precipitation in Five Continents,* Smithsonian Miscellaneous Collections, volume 151, No. 5, 1967 (Publication 4694).

C. G. Abbot, *Supplement to a Long-Range Forecast of United States Precipitation (Smithsonian Publication 4390),* Smithsonian Miscellaneous Collections, volume 152, No. 5 (Publication 4711).

C. G. Abbot, *Solar Magnetism and World Weather,* Smithsonian Miscellaneous Collections, volume 152, No. 6, 1967 (Publication 4722).

[6] C. G. Abbot, *Solar Variation, a Weather Element,* Proceedings of the National Academy of Sciences, volume 56, No. 6, pages 1627-1634, December 1966.

2 shows large average effects on the temperature of Washington from *rising* and *falling trends* of solar radiation in all months of the year.

TEMPERATURE FORECASTS FOR 19 UNITED STATES CITIES

The temperatures forecasted here for 19 United States cities were computed by us from electronic tabulations by Jonathan Wexler, and were prepared by him from *World Weather Records,* 1880 through 1949. Excepting Nashville, Tennessee, all our long-range predictions extend from 1967 to 1972. For Nashville we predicted from June 1942, so that we could show the effect of bombing—both with uranium preparations, and later with hydrogen bombs—from 1944 to 1964.

TABLE 1.—*Cities Where Temperature is Forecasted*

Bismarck, North Dakota	Galveston, Texas	Phoenix, Arizona
Charleston, South Carolina	Helena, Montana	Portland, Oregon
Chicago, Illinois	Little Rock, Arkansas	Sacramento, California
Cincinnati, Ohio	Marquette, Illinois	Sante Fe, New Mexico
Denver, Colorado	Mobile, Alabama	Spokane, Washington
Eastport, Maine	Nashville, Tennessee	Washington, D.C.
El Paso, Texas		

TABLE 2.—*Normal Monthly Temperatures, in Fahrenheit, for 19 United States Cities, Means, 1880-1949*

A. Sunspots >20. B. Sunspots <20.

	Bismarck		Charleston		Chicago		Cincinnati	
	A	B	A	B	A	B	A	B
January	10.5	8.5	50.9	49.8	27.2	25.0	33.8	32.3
February	10.4	11.2	51.9	51.2	27.6	27.6	34.2	35.0
March	23.3	26.4	56.5	57.7	35.6	37.5	42.4	44.8
April	44.7	42.8	63.9	64.6	48.0	47.2	54.6	54.4
May	55.9	54.5	72.7	72.1	59.2	57.8	65.6	63.9
June	65.6	64.0	78.5	78.1	68.8	67.6	74.0	72.8
July	70.8	77.1	80.7	80.1	74.6	73.5	78.3	76.9
August	67.9	68.7	79.9	80.0	73.0	73.0	75.4	75.1
September	57.5	58.7	76.7	76.4	65.7	66.7	68.7	69.4
October	46.2	44.3	67.3	67.5	55.4	54.8	57.8	57.7
November	29.6	27.7	58.0	58.2	42.3	40.6	45.6	44.7
December	16.4	15.6	52.0	50.8	31.1	29.5	36.6	35.3

	Denver		Eastport		El Paso		Galveston	
	A	B	A	B	A	B	A	B
January	32.1	29.9	21.2	21.4	44.5	43.8	54.9	53.3
February	31.5	32.9	21.6	22.1	49.0	49.4	56.9	55.8
March	37.6	39.4	29.8	29.6	55.2	55.7	60.9	62.2
April	48.5	47.8	38.8	37.6	63.4	63.5	68.6	68.5
May	57.5	56.5	47.4	47.0	72.6	71.8	75.1	74.8
June	68.3	66.5	54.6	54.4	80.5	80.5	80.5	81.0
July	73.2	72.7	59.9	59.5	81.3	81.6	82.7	82.9
August	71.7	71.3	59.7	60.1	80.6	79.3	83.1	80.0
September	62.5	63.2	55.6	55.6	74.5	74.3	79.9	73.1
October	51.6	51.0	47.8	47.6	64.6	64.0	72.7	63.1
November	40.9	38.9	37.1	37.4	52.5	51.7	64.2	56.5
December	32.3	32.8	25.5	26.6	44.7	45.0	56.7	

	Helena		Little Rock		Marquette		Mobile	
	A	B	A	B	A	B	A	B
January	21.9	19.5	43.0	40.6	17.8	16.8	52.2	51.0
February	23.2	23.9	44.2	44.7	16.1	17.3	54.7	53.7
March	31.2	32.8	51.2	53.7	23.8	26.5	58.6	60.2
April	41.6	43.5	62.3	62.2	38.4	38.4	66.4	66.5
May	52.7	52.2	70.1	69.4	50.0	48.1	73.5	73.2
June	60.4	59.6	77.9	77.3	59.5	58.5	79.3	79.4
July	68.2	68.5	81.0	80.5	65.3	65.1	80.5	80.3
August	66.2	67.2	80.0	79.6	63.7	64.0	80.3	80.3
September	55.4	55.8	74.0	74.4	56.9	57.6	77.6	77.5
October	45.8	44.6	63.3	63.5	47.4	46.2	68.0	68.8
November	33.7	32.4	52.8	51.6	34.1	32.9	58.9	58.5
December	23.8	25.3	43.6	43.9	23.1	23.0	53.4	52.3

	Sacramento		Nashville		Phoenix		Portland	
	A	B	A	B	A	B	A	B
January	45.4	45.7	40.2	38.0	51.0	50.8	39.7	38.5
February	50.1	50.5	41.1	41.1	54.8	55.1	41.8	42.2
March	55.0	54.2	47.7	50.8	60.7	60.4	46.8	46.9
April	58.3	59.0	58.8	59.2	67.3	67.8	51.1	51.9
May	63.9	63.9	68.6	67.5	76.0	75.6	57.5	57.5
June	69.2	70.5	76.4	75.4	84.8	84.6	61.8	62.0
July	73.8	74.3	79.4	78.3	90.5	90.0	66.9	67.2
August	72.9	73.5	77.6	77.7	88.7	88.3	66.6	67.3
September	70.8	70.0	72.0	72.4	83.4	82.5	61.7	61.8
October	63.3	63.0	60.6	61.2	71.4	70.6	54.7	53.9
November	54.1	53.7	49.7	48.8	60.1	58.8	46.4	46.1
December	46.2	46.5	41.3	41.5	52.1	52.3	41.0	41.7

	Sante Fe		Spokane		Washington, D. C.	
	A	B	A	B	A	B
January	29.1	28.7	30.1	26.0	35.9	33.9
February	32.8	33.0	30.4	31.6	35.3	35.6
March	39.0	39.2	39.5	39.8	42.5	44.5
April	47.6	47.5	48.4	48.0	53.8	54.5
May	56.5	55.6	56.1	56.0	65.0	64.0
June	66.8	65.3	62.4	62.4	72.9	72.4
July	68.9	68.6	69.7	70.2	76.9	76.3
August	67.7	67.2	68.6	68.9	74.6	74.8
September	61.2	61.5	58.8	59.1	68.7	68.6
October	50.6	50.2	48.9	48.0	57.3	57.5
November	39.2	38.3	37.6	36.9	46.6	46.7
December	30.2	30.4	30.6	30.5	37.1	37.0

As described in several publications listed in the appendix, all of our long-range forecasts, both precipitation and temperature, are compiled by adding the values obtained to represent the weather effects of 27 regular periods, all exact harmonies of 273 months. Hence the forecasts are not *simple* monthly values, but *complex smoothed monthly values.* To compare with them *fairly,* the observed monthly values must also be *smoothed.* The following Tables 3 and 4 give the forecasts, the directly observed monthly values, and the monthly observed values *smoothed* by three-month consecutive smoothing. The differences tabulated in Table 3 are between the monthly forecasts and the three-month smoothed observed temperatures.

THE EFFECTS OF ATOMIC AND HYDROGEN BOMBS ON FORECASTS AT NASHVILLE

Figure 6 in *Solar Variation, a Weather Element* [7] shows graphically how prejudicially the atomic bombing in Japan, and the later hydrogen bombs exploded by the United States and Russia in the Pacific and Arctic Oceans, affected long-range forecasts of precipitation at Tokyo and Lagos. Many similar scatter-graphs of long-range precipitation forecasts at stations in distant regions are on file at the Smithsonian. We wish now to show, in another kind of graph, what effect atmospheric bombing explosions appear to have produced on long-range temperature forecasts in central United States.

[7] Ibid.

Figure 1 graphs the march of long-range temperature forecasts at Nashville, Tennessee, from 1942, before atomic bombs were made, through 1965, after the United States and Russia had exploded mighty hydrogen bombs at intervals from 1949 to 1960.

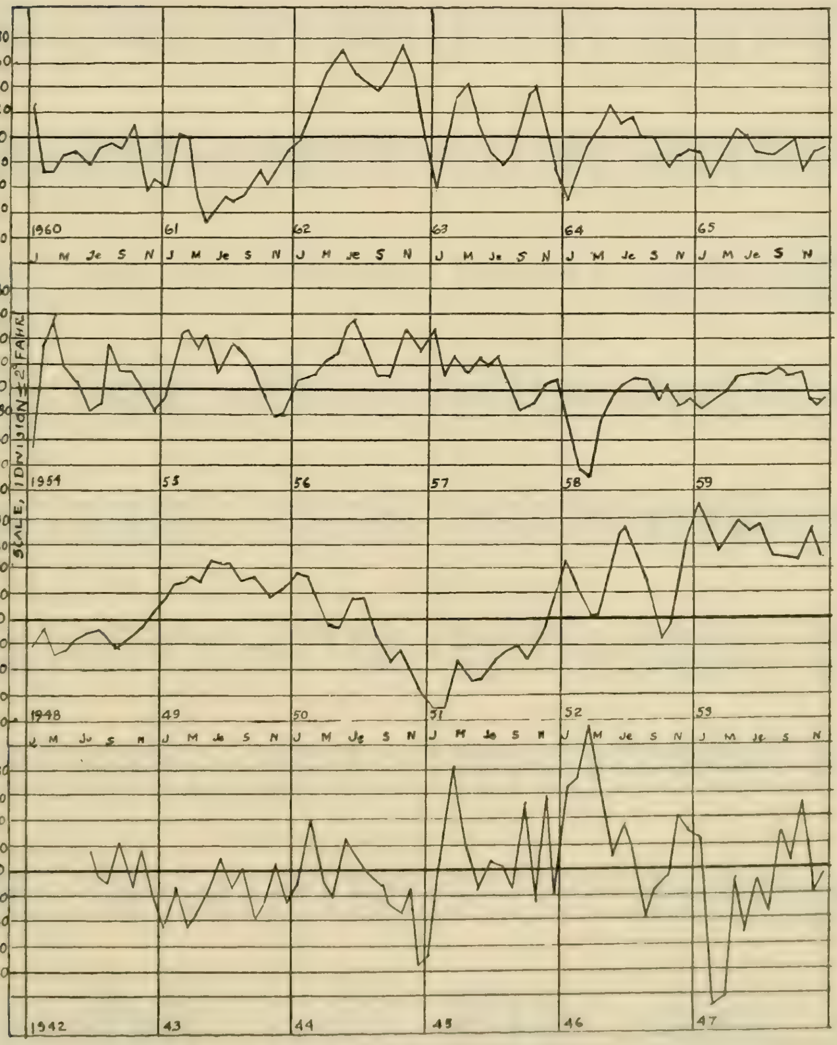

FIGURE 1.—Nashville temperature departures.

TABLE 3.—*Forecast of Temperature Departures from Normal 1968 Through 1972 from Three-month Running Means*

	BISMARCK	CHARLESTON	CHICAGO	CINCINNATI	DENVER	EASTPORT	EL PASO	GALVESTON	HELENA
1968									
January	—2.5	—1.8	+1.4	+0.9	+1.7	+0.8	+1.5	—1.5	—1.3
February	—3.4	—2.7	—0.9	+1.0	+0.5	+1.6	+1.1	—2.3	—4.7
March	—3.1	—2.4	+1.0	+3.5	+0.9	+0.1	+1.0	—1.4	—2.1
April	—3.3	—2.2	+0.4	+3.4	—0.5	—1.1	—0.1	—2.2	—3.5
May	—2.4	—1.6	+0.9	+4.0	+1.2	—1.4	+1.0	—0.7	—3.2
June	—2.8	—0.9	—0.7	+4.8	+1.1	—1.7	+0.8	+0.9	—3.3
July	—1.2	—0.2	—0.1	+3.5	+1.4	—3.4	+0.2	+0.1	—0.5
August	—2.3	+0.4	—0.6	+3.0	+2.4	—4.1	—0.5	+0.3	—3.2
Sepetmber	—2.9	—1.4	—1.8	+1.5	+1.8	—4.1	—0.2	+0.5	—2.1
October	+1.3	—1.4	+0.3	+2.3	+3.6	—2.3	—0.7	+1.0	+0.3
November	+1.7	—1.5	—1.3	+1.0	+1.9	—1.7	—1.7	—0.3	+0.6
December	+1.9	—1.8	+1.0	+1.9	+3.8	—1.4	—0.3	+0.8	+3.3
1969									
January	+2.5	—1.3	+1.9	+1.0	+1.0	—1.2	+1.1	+0.9	+2.9
February	+1.8	—1.4	+2.1	+2.3	+1.3	—0.8	+1.5	+0.8	+0.5
March	+1.3	—1.6	+1.7	+1.2	—0.2	+0.5	+1.5	—0.4	+1.1
April	—0.2	—1.5	+3.3	+0.8	+0.1	+1.1	+2.1	+0.4	+2.5
May	—1.2	+1.5	+3.9	+1.3	—0.8	—0.1	+2.4	—0.9	+3.1
June	—1.5	—0.6	+4.2	+2.3	—1.6	+0.3	+2.1	+0.3	+3.0
July	—0.9	+0.7	+3.4	+2.1	—2.5	+2.6	+1.8	+0.9	+1.5
August	+0.8	+2.0	+4.0	+3.6	—3.1	+2.2	+0.8	0.0	+2.0
September	—1.6	+3.0	+5.6	+4.8	—3.3	+2.2	+0.4	+0.9	+1.0
October	—0.7	+3.3	+4.3	+3.4	—3.8	+3.5	—0.1	+0.9	+1.5
November	—1.7	+2.9	+3.4	+3.1	—2.3	+2.8	—0.4	+2.4	—1.6
December	—2.2	+4.5	+2.7	+2.8	—5.2	+4.0	—1.0	—0.3	—3.0
1970									
January	—0.8	+4.8	+2.9	+2.2	—4.9	+2.9	—2.6	+1.9	—0.4
February	+1.0	+4.3	+3.5	+2.0	—3.1	+0.5	—0.6	+2.0	—0.4
March	+0.3	+3.7	+2.3	+2.2	—2.6	+2.3	—0.1	+1.3	—0.8

April	+0.3	+4.8	+1.3	+1.2	−2.1	+2.4	−0.6	+1.8	−1.0
May	+0.2	+4.4	+2.5	+1.9	−1.2	+2.1	+0.7	+2.3	+1.1
June	+0.3	+3.2	+1.6	−3.1	+0.6	+0.9	+0.6	+1.5	+3.2
July	0.0	+2.3	+1.6	−0.2	+1.4	+0.2	−1.3	+2.6	+3.1
August	+0.8	+1.5	−0.7	−0.8	+0.4	+0.6	+2.5	+3.4	+4.5
September	+1.0	+1.5	−0.8	−1.7	+2.3	−0.4	+3.1	+1.8	+3.8
October	+1.4	+1.0	+1.1	−2.4	−0.1	−2.0	+3.2	+2.9	+3.0
November	−1.9	−2.0	+0.7	−2.0	+0.8	−2.7	+3.4	+2.7	+3.1
December	−1.1	−3.2	+0.4	−2.9	−0.3	−3.0	+3.4	+2.8	+2.1
1971									
January	−3.8	−3.3	+0.1	−3.1	−0.6	−2.7	+4.4	+2.5	+1.6
February	−2.1	−2.7	+0.6	−4.6	−0.6	−2.8	+3.6	+3.6	+1.8
March	−3.6	−1.9	−0.3	−3.2	0.0	−2.1	+3.7	+3.3	+0.8
April	−4.4	−1.3	+0.5	−3.0	+0.3	−2.6	+3.5	+3.7	+1.3
May	−5.0	−1.6	−1.3	−4.3	+0.6	−2.1	+2.0	+3.3	+1.5
June	−4.7	−1.4	−0.6	−4.2	−0.8	−1.5	+1.9	+2.0	−1.0
July	−2.4	−1.0	−0.4	−5.6	+1.0	−1.5	+2.2	+3.1	+1.2
August	−2.8	+0.5	−3.4	−5.1	+0.5	−1.8	+1.6	+3.9	−0.4
September	−3.2	+0.6	−2.0	−5.6	+0.8	+0.1	+1.6	+3.4	−1.1
October	−1.3	+1.1	−3.3	−5.0	+1.5	+0.3	+0.1	+2.0	+0.4
November	+0.5	+0.3	−6.1	−5.3	+3.6	+0.7	+1.2	+1.9	+0.2
December	+3.5	+1.1	−6.1	−4.3	+3.8	+1.5	+1.9	+1.0	+0.4
1972									
January	+2.8	+0.2	−3.5	−4.6	+3.9	+2.5	+1.8	+0.9	+1.0
February	+6.3	−0.4	−3.0	−3.0	+5.9	+3.0	+2.9	+1.1	+2.8
March	+5.9	−0.5	−0.5	−2.1	+5.6	+2.5	+3.1	−1.0	+3.5
April	+8.0	−0.5	−1.4	−2.0	+6.0	+2.5	+5.4	−1.3	+1.8
May	+8.6	−0.8	−2.0	−1.2	+4.3	+1.6	+5.0	−0.3	+5.1
June	+10.7	−0.1	−2.4	−0.1	+4.3	+2.1	+4.9	+0.6	+3.8
July	+10.7	+0.6	−0.4	+0.9	+4.2	+1.8	+5.1	−0.1	+3.7
August	+12.3	+1.7	+0.7	+3.1	+5.6	+0.7	+5.9	+2.3	+2.9
September	+10.2	+2.5	−0.3	+2.8	+3.7	+0.6	+5.2	+2.0	+0.7

TABLE 3.—*continued*

	Little Rock	Marquette	Mobile	Sacramento	Nashville	Phoenix	Portland	Santa Fe	Spokane	Washington, D. C.
1968										
January	−0.7	−1.1	+0.7	0.0	−0.2	−0.2	−1.3	−1.0	+4.7	−0.1
February	−2.4	+1.0	−0.6	+0.5	−1.2	−1.8	+0.9	−3.2	+4.1	+0.1
March	−0.5	+1.2	+1.0	+0.1	−2.4	−1.2	−0.1	+0.1	+5.2	+0.3
April	0.0	+1.0	+0.3	+0.3	−2.1	+0.9	+0.6	−1.6	+5.7	+0.7
May	+0.5	+2.0	+0.5	−0.2	−2.4	+0.3	+1.1	−0.7	+5.9	+1.1
June	+1.4	+2.0	+0.7	+0.2	−3.1	−0.3	+0.9	−1.1	+6.2	+0.9
July	+1.3	+2.1	−0.4	−0.7	−4.5	−1.1	+1.4	−0.1	+4.8	−0.6
August	+1.2	+0.6	−0.7	−2.0	−5.0	+2.6	+1.2	−0.3	+3.1	−0.6
September	−0.4	−0.8	−1.9	−0.5	−5.2	+1.3	+1.3	+0.7	+0.9	−2.2
October	+1.3	+1.8	−1.8	+0.9	−5.5	+2.0	+1.6	0.0	+2.3	−1.7
November	−0.4	0.0	−1.9	+0.9	−4.9	+2.2	+1.0	−0.6	+0.4	−0.8
December	+1.4	+3.5	−1.7	+1.2	−3.9	+2.0	+1.7	+0.5	+0.5	−1.1
1969										
January	+1.1	+2.8	−1.8	+1.9	−1.4	+1.8	+0.9	+0.6	+0.6	−0.3
February	+0.8	+2.6	−1.4	+3.6	−1.6	+1.9	+0.6	+0.6	−0.9	+0.6
March	−0.2	−0.1	−1.6	+3.6	−2.1	+2.5	−0.6	−0.3	−0.9	−0.6
April	+0.9	+1.5	−1.2	+3.8	−1.3	+1.4	−1.1	+0.6	−0.3	−0.1
May	+1.3	+0.3	−0.8	+3.3	−0.3	+1.9	−1.5	+1.4	0.0	+1.4
June	+1.2	+2.7	+0.5	+2.7	+0.4	+3.0	−1.6	+1.8	+0.4	−0.8
July	+2.1	+0.3	+1.1	+1.8	+0.5	−0.1	−0.6	+2.2	+0.6	+0.5
August	+2.8	+2.3	+0.9	+1.0	+1.8	+0.1	−1.0	+2.5	+0.6	+0.8
September	+3.9	+2.2	+1.1	−0.3	+2.2	−0.9	−0.5	+3.0	+1.7	+1.2
October	+3.3	+4.5	+1.2	+0.3	+3.0	+0.4	−0.8	+2.0	+0.4	+0.9
November	+3.1	+1.6	+1.2	−0.7	+1.0	−1.0	+0.2	+1.9	−0.9	+0.9
December	+2.3	+1.6	+1.8	−0.6	+2.1	−1.2	−0.3	+1.2	+0.2	+1.8
1970										
January	+1.4	+3.1	+1.5	−1.0	+2.0	+0.1	−0.3	+1.2	−0.3	+1.5
February	+2.3	+3.7	+1.8	−1.2	+2.5	+1.9	−0.1	+2.6	−1.2	+1.3
March	+0.7	+3.0	−0.1	−0.1	+0.9	+0.3	+0.3	+3.3	−2.2	+0.8

April	—0.5	+2.9	—0.4	—0.8	+1.0	+1.8	—0.7	+2.1	—3.6	+1.4
May	+0.1	+3.9	—0.1	+0.2	+0.3	+2.5	+0.1	+3.3	—2.7	+1.8
June	—1.3	+3.1	—0.6	+1.8	+0.4	+2.3	+1.2	+3.1	—3.9	+0.4
July	—1.6	+2.4	—0.7	+0.6	+0.7	+1.7	+1.0	+4.1	—3.4	+1.2
August	—2.4	+0.4	—0.9	+2.0	+0.4	+2.4	+1.0	+4.7	—3.2	+1.3
September	—1.6	—0.7	—1.0	+0.3	—0.6	+1.7	+0.4	+4.9	—4.2	+1.6
October	—1.7	—0.5	—1.7	+0.9	—1.4	—1.0	+0.2	+3.1	—3.6	+2.3
November	—1.5	+0.9	—2.4	+1.2	—1.7	+2.7	+0.2	+2.5	—3.2	+2.4
December	—1.7	—1.9	—1.7	+0.5	—2.6	+1.6	—0.4	+2.1	—3.8	+0.5
1971										
January	—1.8	—2.7	—0.9	—0.5	—2.9	+1.5	—1.1	+2.6	—2.5	—1.6
February	—1.6	—4.9	—0.9	—0.5	—1.9	+3.0	—0.6	+2.1	—3.2	—1.0
March	—0.5	—3.2	+1.1	—1.1	—1.0	+1.9	0.0	+1.6	—2.4	—0.8
April	+0.6	—6.4	+1.7	—1.3	—1.9	—0.4	—0.8	+0.7	—1.5	—1.7
May	+0.5	—4.9	+0.9	—1.3	—2.8	+2.5	—1.0	—0.2	—1.2	—1.4
June	+1.1	—7.0	+0.6	—0.8	—2.3	+0.6	+0.4	—1.1	+0.6	—2.9
July	+1.3	—6.7	+2.7	—1.4	+0.1	—0.1	+1.4	—0.9	+1.1	—3.5
August	+1.1	—6.0	+1.6	—1.7	+0.1	—0.5	+2.0	—1.5	+2.4	—4.3
September	+1.4	—5.1	+1.3	—1.9	+0.9	—2.1	+2.0	—0.9	+2.1	—3.8
October	+2.6	—6.7	+1.0	—2.8	+0.8	—2.2	+3.7	—3.2	+2.3	—3.4
November	+2.0	—4.4	+1.6	—1.6	+2.2	—1.8	+3.9	—2.3	+1.9	—2.8
December	+1.9	—3.9	+1.7	—0.6	+3.3	—1.5	+4.3	—2.2	+3.1	—3.0
1972										
January	+2.6	—4.1	+2.4	+0.2	+3.6	—1.0	+3.4	—2.4	+2.5	—1.3
February	+3.3	—4.2	+1.3	+1.3	+3.9	+0.4	+4.3	—1.6	+4.3	—1.6
March	+3.0	—0.9	+0.5	+1.8	+4.4	+2.5	+4.3	—1.8	+5.1	—0.5
April	+2.5	—2.2	+0.5	+2.8	+3.4	+0.7	+2.5	—0.9	+5.1	—0.9
May	+1.6	—0.9	0.0	+2.6	+3.8	+2.9	+2.4	—1.6	+6.3	+0.2
June	+2.2	+0.8	—0.8	+2.1	+1.3	—0.2	+1.3	—0.6	+6.7	+1.4
July	+3.6	+0.4	+2.7	+2.0	+2.8	+1.4	+0.4	—0.4	+6.4	+0.8
Auggust	+3.2	+1.1	+3.6	+1.5	+2.9	—0.4	+0.6	—1.0	+6.6	+2.9
September	+2.4	+1.2	+3.7	—0.5	+1.7	—1.0	—0.5	—1.8	+3.5	+3.2

TABLE 4.—*Four-month Mean Temperatures, 1965-1972*
All based on three-month running mean data

Bismarck	Predicted	Observed	Δ
1965			
I		−3.3	
II	+5.7	−4.2	−9.9
III	+2.7	0.0	−2.7
1966			
I	−0.9	+1.6	+2.5
II	−0.6	−3.2	−2.6
III	−0.2	−1.6	−1.4
1967			
I	+4.0	+0.8	−3.2
II	+2.6	−4.4	−7.0
III	−1.2		
1968			
I	−3.1		
II	−2.2		
III	+1.1		
1969			
I	+1.4		
II	−0.7		
III	−1.6		
1970			
I	+0.2		
II	+0.3		
III	−0.2		
1971			
I	−3.5		
II	−3.7		
III	−0.1		
1972			
I	+5.8		
II	+10.6		
III			

Charleston	Predicted	Observed	Δ
1965			
I		−0.4	
II	+3.3	−0.6	−3.9
III	+2.7	−2.0	−4.7
1966			
I	+3.1	−2.1	−5.2
II	+0.9	−3.9	−4.8
III	−0.2	−0.9	−0.7
1967			
I	+1.5	+1.8	+0.3
II	−3.0	−1.8	+1.2
III	−3.8		
1968			
I	−2.3		
II	−0.6		
III	−1.5		
1969			
I	−1.4		
II	+0.9		
III	+3.4		
1970			
I	+4.4		
II	+2.8		
III	−0.7		
1971			
I	−2.3		
II	−0.9		
III	+0.8		
1972			
I	−0.3		
II	+0.4		
III			

Chicago	Predicted	Observed	Δ
1965			
I		−0.6	
II	+4.4	−1.8	−6.2
III	+3.0	−1.4	−4.4
1966			
I	−3.2	−0.7	+2.5
II	−3.6	−0.9	+2.7
III	−2.1	−0.2	+1.9
1967			
I	−1.8	+1.0	+2.8
II	−1.6	−1.0	+0.6
III			
1968			
I	+0.5		
II	−0.1		
III	−0.4		
1969			
I	+2.2		
II	+3.9		
III	+4.0		
1970			
I	+2.5		
II	+1.2		
III	+0.4		
1971			
I	+0.2		
II	−1.4		
III	−4.4		
1972			
I	−2.1		
II	−1.0		
III			

TABLE 4.—*continued*

	Cincinnati				Denver				Eastport		
	Pre-dicted	Ob-served	Δ		Pre-dicted	Ob-served	Δ		Pre-dicted	Ob-served	Δ
1965				*1965*				*1965*			
I		−1.5		I		−1.6		I		+2.5	
II	+2.6	−3.5	−6.1	II	−0.4	−3.4	−3.0	II	+2.4	+5.2	+2.8
III	−0.2	−2.1	−1.9	III	+3.0	+1.1	−1.9	III	+2.5	+1.3	−1.2
1966				*1966*				*1966*			
I	−2.1	−2.1	0.0	I	+2.8	+0.4	−2.4	I	+2.7	+2.6	−0.1
II	−2.5	−0.9	+1.8	II	−0.6	−1.6	−1.0	II	+1.1	+2.9	+1.8
III	−1.7	+0.4	−0.2	III	−3.2	+1.4	+4.6	III	+1.5	+1.6	+0.1
1967				*1967*				*1967*			
I	−0.7	+0.1	+0.8	I	−2.1	+2.8	+4.9	I	+1.7	+0.4	−1.3
II	−2.8	−1.0	+1.8	II	+0.8	−4.9	−5.7	II	+1.2	+4.9	+3.7
III	−1.6	−1.8	−0.2	III	+1.2			III	+0.8		
1968				*1968*				*1968*			
I	+2.2			I	+0.6			I	+0.4		
II	+3.8			II	+1.5			II	−2.6		
III	+1.7			III	+2.8			III	−2.4		
1969				*1969*				*1969*			
I	+1.3			I	+0.6			I	−0.1		
II	+2.3			II	−2.0			II	+1.2		
III	+3.5			III	−3.6			III	+3.1		
1970				*1970*				*1970*			
I	+1.9			I	−3.2			I	+2.0		
II	−0.6			II	+0.3			II	+1.0		
III	−2.2			III	+0.7			III	−2.0		
1971				*1971*				*1971*			
I	−3.5			I	−0.2			I	−2.6		
II	−4.8			II	+0.3			II	−1.7		
III	−5.0			III	+2.4			III	+0.6		
1972				*1972*				*1972*			
I	−2.9			I	+5.4			I	+2.6		
II	+0.7			II	+4.6			II	+1.6		
III				III				III			

TABLE 4.—*continued*

	El Paso			Galveston			Helena		
	Predicted	Observed	Δ	Predicted	Observed	Δ	Predicted	Observed	Δ
1965									
I		+0.2	+1.1		0.0			+1.6	
II	−1.7	−0.6	−2.7	+2.4	+0.2	−2.0	+1.8	−3.3	−5.1
III	+1.1	−1.6		+3.4	+1.2	−2.2	+2.0	+0.7	−1.3
1966									
I	+2.9	−0.6	−3.5	+2.2	−1.5	−3.1	+1.6	+3.2	+1.6
II	+2.3	−0.9	−2.2	+0.8	−1.2	−2.0	+2.2	−1.0	−3.0
III	+0.5	−0.4	−0.9	−1.7	−0.2	+1.5	−0.4	+4.5	+4.9
1967									
I	−0.1	+1.0	+1.1	−2.2	+2.4	+4.6	−2.6	+3.0	+5.6
II	+1.4	−1.3	−2.7	−3.0	−0.8	−2.2	−2.6	−0.4	+2.2
III	+1.6			−3.0			−2.2		
1968									
I	+0.9			−1.8			−2.9		
II	+0.4			+0.2			−2.6		
III	−0.7			+0.5			+0.5		
1969									
I	+1.6			+0.4			+1.8		
II	+1.8			+0.1			+2.4		
III	−0.3			+1.0			−0.5		
1970									
I	−1.0			+1.8			−0.6		
II	+0.6			+2.4			+3.0		
III	+3.3			+2.6			+3.0		
1971									
I	+3.8			+3.3			+1.4		
II	+1.9			+3.1			+0.3		
III	+1.2			+2.1			0.0		
1972									
I	+3.3			−0.1			+2.3		
II	+5.2			+0.6			+3.9		
III									

TABLE 4.—*continued*

	Little Rock			Marquette			Mobile		
	Predicted	Observed	Δ	Predicted	Observed	Δ	Predicted	Observed	Δ
1965									
I		−0.2			+1.0			+1.4	
II	+3.1	+0.4	−2.7	+0.7	−1.8	−2.5	+1.0	+0.6	−0.4
III	+1.5	+1.0	−0.5	+0.8	+0.1	−0.7	−0.3	+2.2	+2.5
1966									
I	−1.2	0.0	+1.2	+0.2	+4.4	+4.2	−0.8	−0.1	+0.7
II	−1.6	−0.8	+0.8	+0.3	+0.1	−0.2	−1.2	+0.6	+1.8
III	−0.4	−0.6	−0.2	−1.4	+0.2	+1.6	−0.5	+1.3	+1.8
1967									
I	+1.0	+1.9	+0.9	−1.0	+1.4	+2.4	+1.4	+3.3	+1.9
II	−1.0	−2.0	−1.0	−3.0	−1.2	+1.8	+0.7	0.0	−0.7
III	−3.0			−0.9			+0.2		
1968									
I	−0.9			+0.5			+0.4		
II	+1.1			+1.7			0.0		
III	+0.5			+1.1			−1.8		
1969									
I	+0.6			+1.7			−1.5		
II	+1.4			+1.4			+0.4		
III	+3.2			+2.5			+1.3		
1970									
I	+1.0			+3.1			+0.7		
II	−1.3			+2.4			−0.6		
III	−1.6			−0.6			−1.7		
1971									
I	−0.8			−4.3			+0.2		
II	+1.0			−6.2			+1.4		
III	+2.0			−5.0			+1.4		
1972									
I	+2.8			−3.6			+1.2		
II	+2.6			+0.4			+1.4		
III									

TABLE 4.—*continued*

	Nashville				Phoenix				Portland		
	Pre-dicted	Ob-served	Δ		Pre-dicted	Ob-served	Δ		Pre-dicted	Ob-served	Δ
1965				*1965*				*1965*			
I		−0.3		I		−1.9		I		−0.1	
II	+1.6	−0.7	−2.3	II	−0.3	−3.8	−3.5	II	−1.0	+1.7	+2.7
III	+2.7	+0.8	−1.9	III	−0.2	+0.7	+0.9	III	−0.9	+1.5	+2.4
1966				*1966*				*1966*			
I	+3.6	+0.4	−3.2	I	−1.5	+0.3	+1.8	I	−1.2	+0.9	+2.1
II	+1.7	−1.8	−3.5	II	−1.4	+1.2	+2.6	II	−0.2	−0.7	−0.5
III	+1.4	−0.8	−2.2	III	−2.1	−0.3	+1.8	III	−0.3	+1.4	+1.7
1967				*1967*				*1967*			
I	+1.2	+2.9	+1.7	I	−1.8	+0.2	+2.0	I	−2.0	+0.6	+2.6
II	+1.1	−2.7	−3.8	II	−1.4	−1.5	−0.1	II	−1.5	+1.4	+2.9
III	+1.1			III	−2.2			III	−0.7		
1968				*1968*				*1968*			
I	−1.5			I	−0.6			I	0.0		
II	−3.8			II	+0.4			II	−1.2		
III	−4.9			III	+1.9			III	+1.4		
1969				*1969*				*1969*			
I	−1.6			I	+1.9			I	−0.1		
II	+0.6			II	+1.2			II	−1.2		
III	+1.8			III	−0.7			III	−0.4		
1970				*1970*				*1970*			
I	+1.6			I	+1.0			I	−0.2		
II	+0.4			II	+2.2			II	+0.8		
III	−1.6			III	+1.8			III	+0.1		
1971				*1971*				*1971*			
I	−1.9			I	+1.5			I	−0.6		
II	−1.2			II	+0.6			II	+0.7		
III	+1.8			III	−1.9			III	+3.5		
1972				*1972*				*1972*			
I	+3.8			I	+0.6			I	+3.6		
II	+2.7			II	+0.9			II	+1.2		
III				III				III			

TABLE 4.—*continued*

	Sacramento			Santa Fe			Spokane		
	Predicted	Observed	Δ	Predicted	Observed	Δ	Predicted	Observed	Δ
1965									
I		0.0			+7.6			−1.5	
II	−1.2	−1.4	−0.2	+1.0	+4.8	+3.8	−4.5	−4.1	+0.5
III	+1.4	0.0	−1.3	+1.6	+6.7	+5.1	−2.7	+0.8	+3.5
1966									
I	+1.8	+0.2	−1.6	+1.6	+5.3	+3.7	−0.5	+0.6	+1.1
II	−0.5	+0.7	+1.2	+1.2	+7.2	+6.0	+1.0	−2.5	−3.5
III	−3.5	+1.3	+4.8	+0.1	+6.7	+6.6	−2.6	+1.6	+4.2
1967									
I	−2.3	−2.4	−0.1	−0.8	+7.0	+7.8	−5.2	+1.4	+6.6
II	+1.0	+0.7	−0.3	+0.8	+9.4	+8.6	+1.1	−0.7	+0.4
III	+1.1			−0.5			+2.1		
1968									
I	+0.2			−1.4			+4.9		
II	−0.6			−0.6			+5.8		
III	+0.6			+0.2			+1.0		
1969									
I	+3.2			+0.4			−0.4		
II	+2.2			+2.0			+0.4		
III	−0.3			+2.0			+0.4		
1970									
I	−0.8			+2.3			−1.7		
II	+1.2			+3.8			−3.3		
III	+0.7			+3.2			−3.7		
1971									
I	−0.8			+1.8			−2.4		
II	−1.3			−0.9			+0.7		
III	−1.7			−2.2			+2.4		
1972									
I	+1.5			−1.7			+4.4		
II	+2.0			−0.9			+6.5		
III									

TABLE 4.—*continued*

	Washington, D. C.		
	Predicted	Observed	Δ
1965			
I		+1.0	
II	+2.5	+0.1	—2.4
III	+0.8	+2.9	+2.1
1966			
I	—0.8	+3.0	+3.8
II	—0.7	+1.0	+1.7
III	—0.3	+1.9	+2.2
1967			
I	—0.8	+2.3	+3.1
II	—1.8	—0.8	+1.0
III	—1.7		
1968			
I	+0.2		
II	+0.2		
III	—1.4		
1969			
I	+0.1		
II	+0.5		
III	+1.2		
1970			
I	+1.2		
II	+1.2		
III	+1.7		
1971			
I	—1.3		
II	—3.0		
III	—3.2		
1972			
I	—1.1		
II	+1.3		
III			

It is plain that the graph comprises intervals of good forecasts and intervening intervals of distorted forecasts. These intervals may be tabulated as follows:

Period of good forecasts	Number of months		Mean observed minus predicted	
June 1942 to November 1944	30		20	
April 1947 to January 1949	22		30	
February 1957 to March 1961	50		15	
March 1964 to December 1965	21		15	
Total number of months of good forecasts		123		80
Mean (80 ÷ 4) = 20				
Period of disturbed forecasts				
December 1944 to March 1947	28		45	
February 1949 to January 1957	96		42	
March 1961 to February 1964	36		40	
Total number of months of disturbed forecasts		160		127
Total months of forecasts		283		
Mean (127 ÷ 3) = 42				

Volcanoes and bombs produce similar effects. In Volume 4 of the *Annals of the Smithsonian Astrophysical Observatory,* page 128, the effect of the eruption of the volcano Katmai, 6 June 1912, is recorded in tabulating the multitude of pyrheliometer and bolometric-spectral observations made at Mount Wilson in 1912, 1913, and 1914. With a general mean of 1.370 calories in pyrheliometer readings, the departures noted in Augusts of 1912, 1913, and 1914 were as follows:

1912............–.239
1913............–.101
1914............–.022

So it is not remarkable to find that, in various intervals of months and years, large discrepancies between long-range forecasts (based on normal atmospheric conditions) occurred after the bombing between 1944 and 1960.

APPENDIX

Publ. No.	Date	Smithsonian Miscellaneous Collections	Title and Author
2825	1925	Volume 77, No. 5	*Solar variation and forecasting,* C. G. Abbot
3114	1931	Volume 85, No. 1	*Weather dominated by solar changes,* C. G. Abbot
3339	1935	Volume 94, No. 10	*Solar radiation and weather studies,* C. G. Abbot
3637	1941	Volume 101, No. 1	*An important weather element hitherto generally disregarded,* C. G. Abbot
3641	1941	Volume 101, No. 5	*On solar-constant and atmospheric temperature changes,* Henryk Arctowski
3765	1944	Volume 104, No. 3	*A 27-day period in Washington precipitation,* C. G. Abbot
3771	1944	Volume 104, No. 5	*Weather predetermined by solar variation,* C. G. Abbot
3807	1945	Volume 104, No. 13	*Correlations of solar variation with Washington weather,* C. G. Abbot
3893	1947	Volume 107, No. 4	*The sun's short regular variation and its large effect on terrestrial temperatures,* C. G. Abbot
3901	1947	Volume 107, No. 9	*Precipitation affected by solar variation,* C. G. Abbot
3916	1948	Volume 110, No. 1	*Solar variation attending West Indian hurricanes,* C. G. Abbot
3940	1948	Volume 110, No. 6	*Magnetic storms, solar radiation, and Washington temperature changes,* C. G. Abbot
3990	1949	Volume 111, No. 13	*Short periodic variations and the temperatures of Washington and New York,* C. G. Abbot
4015	1950	Volume 111, No. 17	*Periodic influence of Washington and New York weather of 1949 and 1950,* C. G. Abbot
4088	1952	Volume 117, No. 10	*Periodicities in the solar-constant measures,* C. G. Abbot
4090	1952	Volume 117, No. 11	*Important interferences with normals in weather records, associated with sunspot frequency,* C. G. Abbot
4103	1953	Volume 121, No. 5	*Solar variation and precipitation at Albany, N.Y.,* C. G. Abbot
4135	1953	Volume 122, No. 4	*Solar variation a leading weather element.* C. G. Abbot
4211	1955	Volume 128, No. 3	*Sixty-year weather forecasts,* C. G. Abbot
4213	1955	Volume 128, No. 4	*Periodic solar variation,* C. G. Abbot

Publ. No.	*Date*	*Smithsonian Miscellaneous Collections*	*Title and Author*
4222	1955	Volume 131, No. 1	*Leading operations of the Smithsonian Astrophysical Observatory, 1895-1955,* C. G. Abbot
4265	1956	Volume 134, No. 1	*Periods related to 273 months or 22¾ years,* C. G. Abbot
4338	1958	Volume 135, No. 10	*Periodicities in ionospheric data,* C. G. Abbot
4352	1959	Volume 138, No. 3	*Long-range weather forecasting.* C. G. Abbot
4390	1960	Volume 139, No. 9	*A long-range forecast of United States precipitation.* C. G. Abbot
4462	1961	Volume 143, No. 2	*Sixteen-day weather forecasts from satellite observations,* C. G. Abbot
4471	1961	Volume 143, No. 5	*A long-range temperature forecast.* C. G. Abbot
4545	1963	Volume 146, No. 3	*Solar variations and weather,* C. G. Abbot
4656	1966	Volume 148, No. 7	*An account of the Smithsonian Institution, 1904-1953,* C. G. Abbot
4659	1966	Volume 148, No. 8	*Forecasting from harmonic periods in precipitation,* C. G. Abbot
4694	1967	Volume 151, No. 5	*Precipitation in five countries,* C. G. Abbot
4711	1967	Volume 152, No. 5	*Supplement to a long-range forecast of United States precipitation,* C. G. Abbot
4722	1967	Volume 152, No. 6	*Solar magnetism and world weather.* C. G. Abbot